NOISE ABATEMENT AT FMC HOLLISTER SITE

Kathy H. Spivey
Wilfred Baker Engineering, Inc.

Dr. Wilfred E. Baker
Wilfred Baker Engineering, Inc.

ABSTRACT

FMC Corporation conducts extensive outdoor explosives testing at a test site near Hollister, California. There are two, well-separated firing areas on the site, plus a number of explosives storage magazines. Maximum amount of high explosive detonated in any test is about 25 pounds. The nearest property line to a test arena is 1,440 feet, while the nearest inhabited building is the site owner's ranch house, about 3,300 feet NNE of one test arena. However, new housing construction is taking place closer to the site and the problem of noise disturbance is increasing. FMC would like to preserve good community relations. Thus, a feasibility study for noise mitigation at the site was conducted.

This paper gives a review of the site visit and presents a number of options for noise abatement and control including use of suppressive shields, complete containment, variation on munition test structures, aqueous foam, computer-based meteorological focusing predictions and portable sound level measuring systems. It evaluates the options, gives approximate costs, and confidence levels of each option, and gives our conclusions and recommendations. It also includes pertinent references.

BACKGROUND

FMC Corporation requested that a feasibility study for noise mitigation at their test site near Hollister, California be conducted. FMC felt they had good community relations in Hollister, and did not want to jeopardize these relations. To assure that community disturbance was minimized, various methods of noise mitigation for their explosives testing were studied. Work included a visit to the Hollister site; discussions with FMC personnel regarding testing facility layout, arrangements, and constraints; and reporting of various mitigation techniques, availability of equipment, and success confidence levels for each technique.

There are two firing arenas on the site and a number of explosive storage magazines. All magazines conform to government explosives storage criteria, and are not of concern in noise mitigation. At the Hollister site, there are no off-site restrictions based on U.S. Government explosives safety regulations and standards (Quantity-Distance Standards) even with much greater than 25 pounds of explosive detonated at either firing arena. The city of Hollister is west of the site. Both areas are located in natural arroyos in the hilly countryside. The maximum amount tested has been 17 pounds of high explosive (HE). FMC wished to test up to 25 pounds total HE at either arena. There is no blast containment at any of the present firing sites, but there is extensive barricading.

Arena #1 has two firing pads and an explosives arena. One firing pad is arranged for flash x-ray and high-speed camera instrumentation of detonating hardware. There are protective barricades for the flash x-ray equipment and cameras. The other firing pad is used primarily for gun launch and impact testing. Much of the equipment tested or used for diagnostics is heavy, so forklift access to all parts of the arenas is a necessity. This arena also has an explosives loading room and a

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well-barricaded firing bunker. Arena #2 is smaller and newer than Arena #1. It too, requires forklift access, has barricades to protect instrumentation, a loading room, and a personnel bunker for instrumentation and firing control.

A number of concepts for explosive noise mitigation were developed using previously analyzed and tested configurations. These were felt to be quite promising for control of off-site noise.

DESCRIPTION OF CONCEPT

Suppressive Shields

In 1968, an Edgewood Arsenal program resulted in the initial concept for suppressive shields (SS). The suppressive shield program was very active in the mid-1970's. Several concepts for fixed, vented panels and structures were developed, analyzed and tested (Refs. 1-13). These uniformly vented panels were intended to strongly attenuate air blast passing through them to a safe level at a prescribed distance, arrest high-speed fragments, and to reduce the diameter of the fireball generated by the explosion.

There is no doubt, from Ref. 1, that suitable suppressive shields can be designed and constructed of standard structural steel components to completely surround each firing site. A rectangular box structure would form the framework for the shield, and vented panels could consist of a number of layers of perforated plates, nested I-beams, or nested angles, as shown in Figure 1. One panel could be a full-height door, large enough for access of a fully-loaded forklift.

The closest safety-approved shield design is the Group 4 design, shown in Figure 2, including a cross-section through a vented panel. This shield has interior dimensions of 9.2 feet wide by 13.1 feet long by 9.3 feet high. It is designed for 10.6 pounds of TNT and a serious fragment hazard. It has been proof tested with 12.7 pounds of TNT in a heavy case.

Although this specific shield design is not large enough, nor does it have a large enough door opening for FMC test arenas, a slightly larger shield with a larger door can be designed and should prove quite adequate. Desired internal dimensions are 16 feet wide with a 6-foot opening full height door in the wall center, 10 feet high and 12 feet deep. Scaled test data summarized in Ref. 1 allow design of a suppressive shield to provide a range of blast wave attenuations.

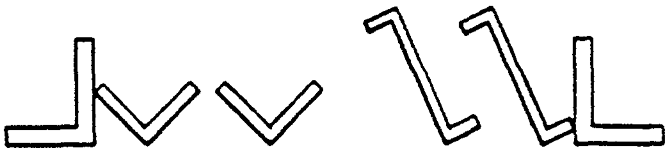
A variation on the suppressive shields concept which could prove to be less expensive to build and more desirable for operations consists of a structure with a strong, welded I-beam framework, with walls filled with dropped-in railroad ties, as shown schematically in Figure 3a. The roof should probably be made of welded, interleaved I-beams, as shown in Figure 3b. The door should open outward for ease in operations, and could be of similar construction to either the walls or roof.

Variation on "Momentum Trap" Structure

Figure 4 is a schematic of the Eglin AFB "momentum trap" test structure. It consists of a pair of massive concrete piers topped by a welded steel I-beam and plate "roof," which is emplaced by a crane, and not tied to the piers. At either end of the internal volume, steel plates are hung from supports allowing the impulse from internal explosions to be converted to plate momentum. The plates are apparently massive enough that plate velocities are low, and plate swing is limited by gravity and air drag.

For tests with up to 25 lbs of HE and fragment impacts, this design would probably be inadequate for repeated tests, because of accumulated blast and fragment damage to the concrete piers. It is strongly suggested that the concrete piers be replaced by a double-walled steel

(a) Nested Angles



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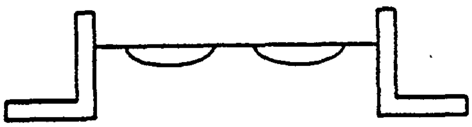

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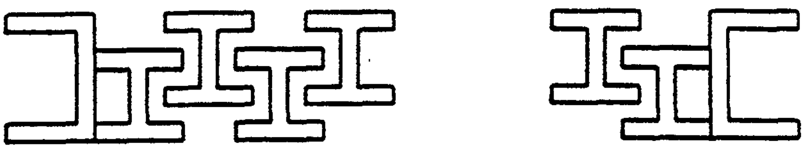

(d) Interlocked I-Beams

Figure 1. Cross-Sections for Some Vented Panel Designs for Suppressive Shields

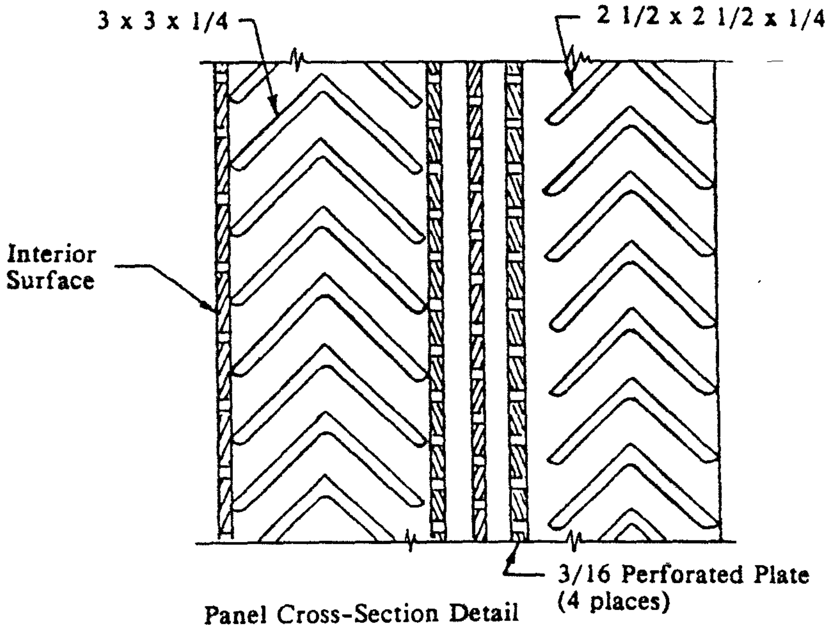

Figure 2. Group 4 Suppressive Shield (Ref. 1)

construction, filled with sand or gravel, as shown in Figure 5. The suspended steel plates could be replaced with woven wire rope blasting mats, which are more flexible and probably less easily damaged by fragment impacts. The "momentum traps" should also be larger than the openings between piers, to prevent them swinging into the interior volume of the structure.

Complete Containment Structures

A number of government and private agencies employ complete containment test fire chambers to mitigate noise from explosive tests. All of these chambers include many portholes and instrument lead passthroughs, so design of these accoutrements is straightforward. For example, U.S. Army Ballistic Research Laboratories use a 30-foot 3-inch thick, steel blast sphere which has an explosive limit of 500 lbs TNT (although it is limited to 20 lbs in repetitive testing); Battelle Memorial Labs uses a cylindrical reinforced-concrete structure with top and bottom domes, 40 feet in diameter and 30 feet in height, with an explosive limit of 50 lbs TNT; EG & G Mound uses a horizontal cylindrical steel chamber 10 feet in diameter and 25 feet in length, with 1-inch wall thickness, with an explosive limit of 10 lbs TNT; and Lawrence Livermore National Laboratory uses horizontal steel cylinders 10 feet in diameter and 25 feet in length, with 2- to 3-inch wall thickness, with an explosive limit of 22 lbs TNT.

The easiest type of blast chamber to analyze is a spherical structure with the explosive charge located in the center. This design does not lend itself to easy access of the facility or efficient utilization of space within the chamber. Complete containment structures have often been designed in pressure vessel geometry, as in Ref. 14, because spherical shells or cylindrical shells with domed ends are more efficient shapes for explosion containment than box-shaped structures. (Material is stressed primarily in tension, rather than bending.)

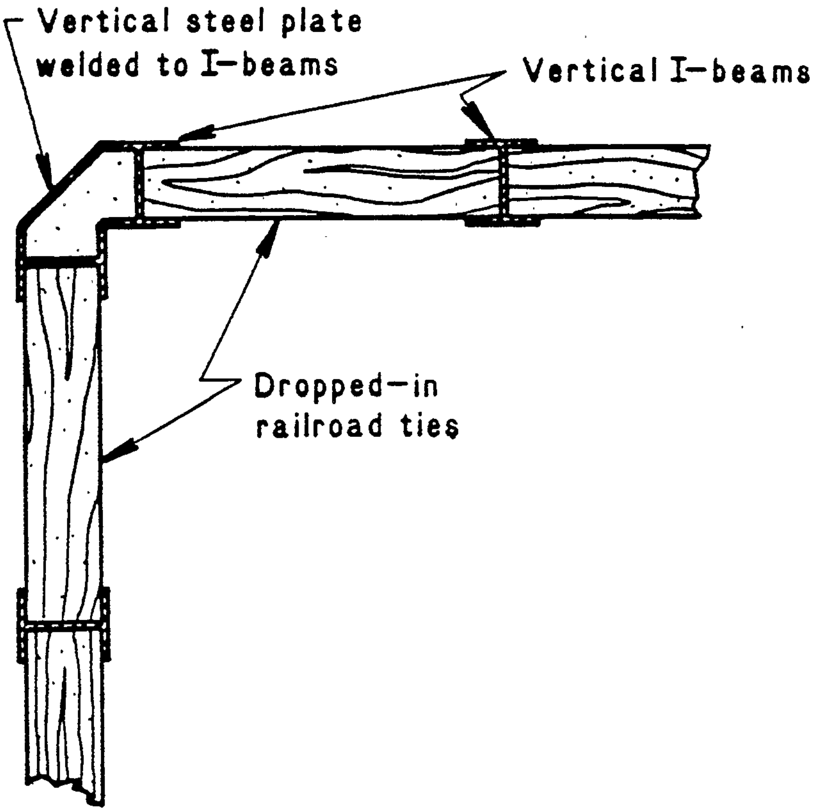

Figure 3A. Schematic Section for Walls of Variation on Suppressive Shields Option

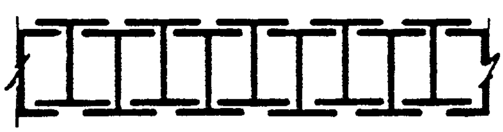

Figure 3B. Section Through Interleaved I-Beam Roof for Suppressive Shield

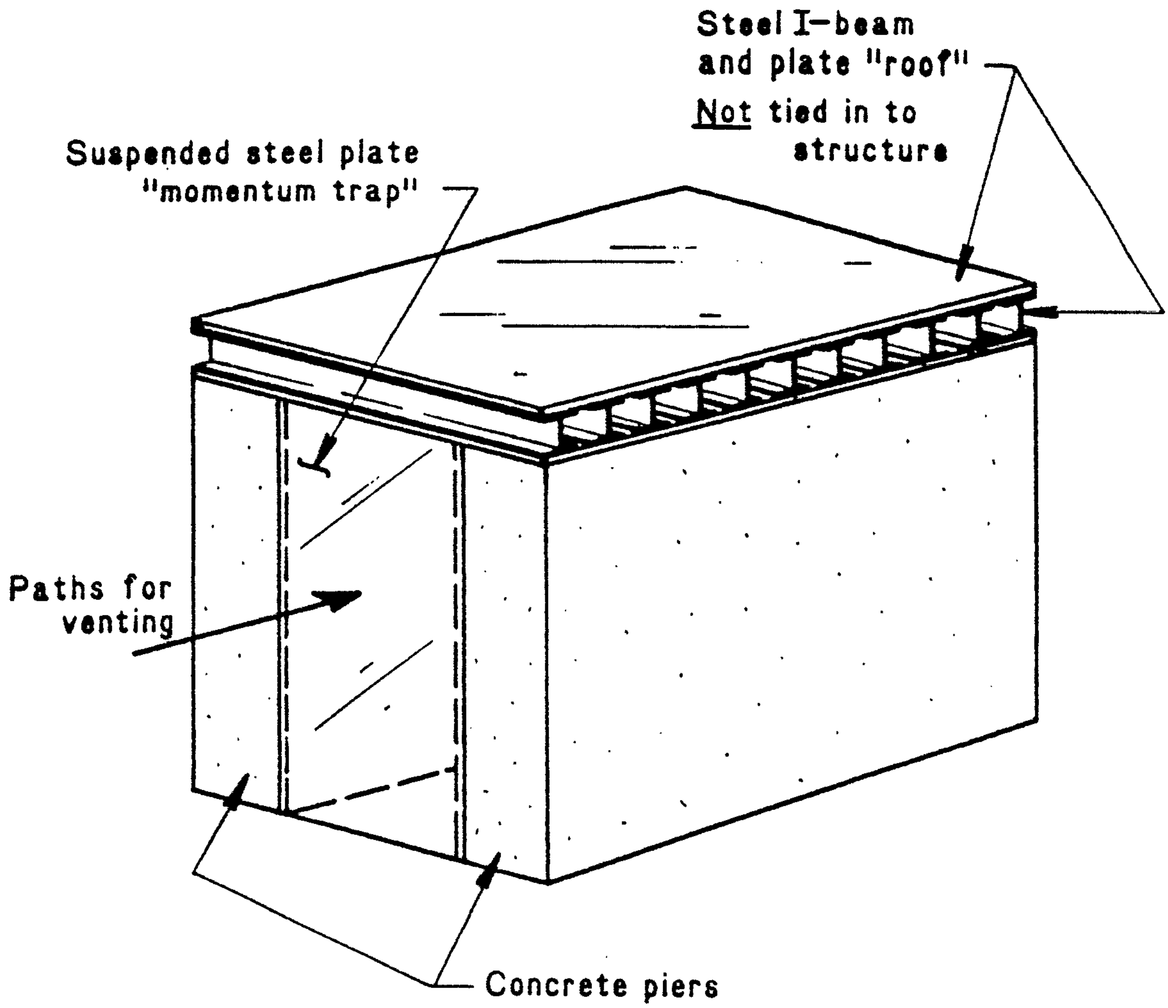

Figure 4. Eglin AFB "Momentum Trap" Test Structure

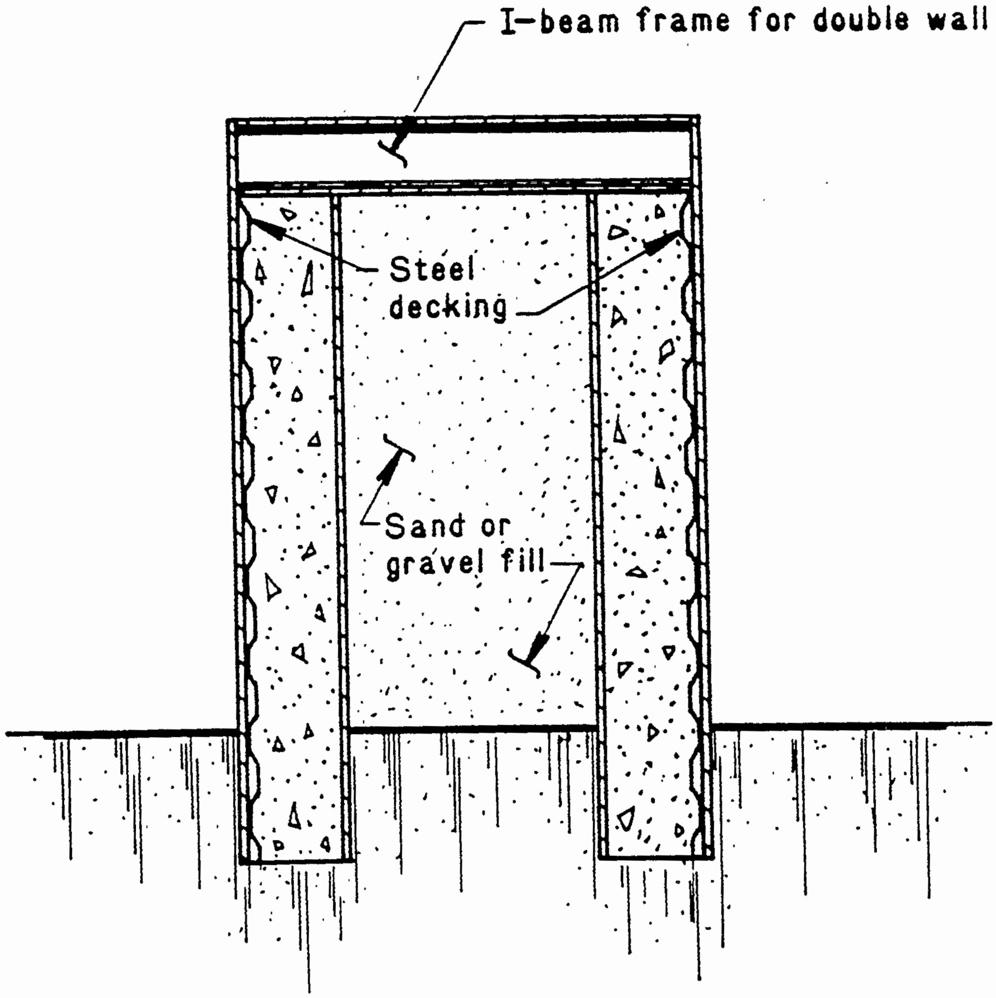

Figure 5. Section Through Filled Double Wall

However, box-shaped structures are usually preferable because of the operational and constructional problems encountered with a spherical or cylindrical blast chamber. Ref. 15 presents a compromise design which was conceived and tested for Battelle Columbus Labs using a circular building with a domed roof and foundation as illustrated in Figure 6. Over 300 charges had been fired of up to 60 lbs of dynamite at the time of reporting. Noise levels at a distance are minimal.

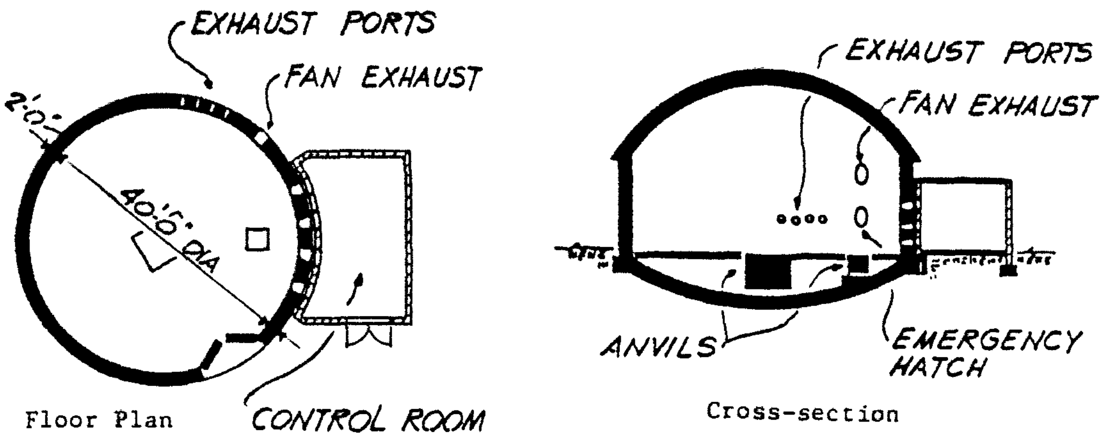

Figure 6. Circular Blast Chamber with Domed Roof and Foundation (Ref. 15)

Complete containment with complete pressure sealing will allow no external air blast from the detonation of an explosive charge within the chamber. Quasi-static pressure will decrease very slowly as heat from the high temperature explosion is transferred to the walls of the chamber, whereby cooling the interior gas and reducing the pressure.

However, complete pressure sealing is not always needed, and a containment can in fact be designed with a small amount of vent area to allow the long-term quasi-static pressure rise to decrease by exiting the chamber through the vent. A small amount of venting will not produce any significant air blast outside the containment (Ref. 16).

Aqueous Foam

Aqueous foams consist of thin sheets of water surrounding pockets of air. Different expansion ratios of the foam can be produced by increasing the surface tension of the water. There has been considerable work done on the attenuation of shock traveling through aqueous foam (Refs. 17 to 20). Possible causes of overpressure decrease are direct energy reduction by cooling of explosives' fireball by the foam through transfer of explosive energy into vaporizing the foam, interference with the explosive afterburn by the foam and the transfer of explosive energy into accelerating the foam surfaces, and shock attenuation by diffusion of the shock wave by multiple reflections from the foam surfaces, possibly diffusing the shock wave by lowering sound velocity, contribution of surface tension effects, and creation of waste energy due to the presence of higher heat capacity materials during expansion (Refs. 17, 21-29).

Blast Focusing Prediction

Certain atmospheric conditions can refract blast energy, which normally would have propagated upward, downward to the ground, causing a focusing effect in a specific area. To determine the focusing conditions one must know the temperature, wind speed, and wind direction as a function of altitude at the test site. Ref. 30 is a good guide for the evaluation of atmospheric effects on blast.

These data can be used for computer-based predictions of blast focusing or defocusing near the test site. Several computer programs have been written to predict blast-focusing and have been validated with test data (Refs. 31-33).

For this option to be viable, a system to launch and track sounding balloons with temperature sensors and telemetry to the surface would have to be purchased or leased. Weather runs should be made shortly before test times for these predictions to be accurate. Results would be the basis for the decision to give clearance to fire.

Less accurate, but perhaps adequate, use of this option would be to request the same detailed weather data which could be recorded at the test site from nearby Air Force bases, or perhaps commercial airports. Data for the closest source could be used in the same manner as data collected from a sounding system at the test site.

Portable Sound Level Monitoring System

One or more portable seismic and sound level monitoring systems could be located in or near areas around the test site where noise complaints could be expected. This type of monitoring system is used often in pre- and post-blast surveys to determine blast vibration effects, such as noise levels, for operations which involve detonations of explosives near populated areas. Monitoring systems could be set up in suspected noise problem areas prior to testing. A test charge much smaller than the main charge would be detonated at the site. Significant noise recorded at the monitoring equipment location would indicate blast focusing conditions which would postpone the main test. Insignificant noise level would indicate safe atmospheric conditions for main charge testing.

APPROXIMATE COSTS ESTIMATES AND CONFIDENCE LEVELS

Suppressive Shields

Construction of a Group 4 suppressive shield was estimated at $105,000 in 1975 dollars. A somewhat larger shield would be needed for each firing site. Including design engineering costs, the larger size, and inflation, cost could be in the range of $200,000-$300,000 per shield.

With this option, design and construction methods are very well proven, so the shield should be sufficient for many repeated, largest size internal explosions, and should strongly attenuate air blast to any desired level. Confidence level for this option is very high.

"Momentum Trap" Structure

Methods for predicting shock and quasi-static pressure loads on this structure, as well as response of the momentum traps, are readily available in the literature. It is likely that the structure, with the piers designed as shown in Figure 5, would be less expensive than a suppressive shield. This option is estimated at $150,000-$250,000 per structure. Confidence level is not quite as high as for Option 1, because such structures have not been proof-tested for repeated firings or noise suppression.

Containment Structure

The cost for a complete containment steel box would probably not exceed the cost for a suppressive shield of the same size and containment capability. This option is estimated at $200,000-$300,000 per structure.

Confidence level for this option is higher than for Option 1, because no objectionable noise can be generated, as proven through a considerable amount of testing.

Aqueous Foam

Testing to prove this option and establish volume of foam needed to achieve desired attenuation levels would be essential. At least 10 tests should be run, with varying HE/foam combinations, and multi-channel air blast instrumentation. Such testing could cost as much as $100,000. Foam equipment and supply costs are not yet known, but prices should be easy to obtain from fire-fighting equipment companies such as Ansul, or may already be available at the test site.

This option could substantially interfere with test objectives for many tests, and so may not be a viable option. The major disadvantage is that the explosive must be completely buried in foam for significant attenuation. This negates motion picture or video coverage of explosive events, but may have little effect on flash x-ray instrumentation. Emplacing foam and subsequent cleanup would also complicate testing. The need for a validation test program before the method can be applied with confidence also lowers its desirability. The confidence level for this option is rated at moderate.

Blast Focusing Prediction

Costs of the tracking equipment are not yet known, but radiosonde balloons are relatively inexpensive, about $100 per balloon, including pressure and temperature recording and telemetry. Chance of successful balloon launch and tracking is 60-70%. The accuracy of the computer blast focus predictions is good, dependent of course on accurate input data.

Acquisition of the needed input data at nearby Air Force bases seldom fails, but the data are suspect for use at Hollister unless collected within several miles of the site. Also, data may not be available near test time.

No changes in present firing arenas are needed, but rather large capital investment in meteorological system and staff training in its use must be made. There is also the possibility of "weather holds" in firing with unfavorable weather conditions. Various uncertainties in this option render the confidence level only moderate.

Local Sound Level Monitoring

Portable monitoring equipment is readily available for lease or purchase. It is relatively inexpensive with the cost of leasing per unit at approximately $600/month. A testing program to "calibrate" the units with small test charges would be essential, but should only cost about $50,000. Operations are complicated somewhat with the necessity of pre-test small shots to establish safety for larger shots, but this method should interfere much less with operations than other options. Perhaps the most attractive feature is direct measurement of noise focus or defocus, at exactly the correct time and shot location.

The confidence level in this method is very high.

CONCLUSIONS AND RECOMMENDATIONS

We conclude that all six of the options have very good potential for noise control/abatement for explosives testing at the Hollister site. The order of confidence level for success of the six options, best to worst, is:

- Certain, Option 3
- Very high, Option 1
- Very high, Option 6
- High, Option 2
- Moderate, Option 4
- Moderate, Option 5

We could only make very approximate cost estimates for each option in this brief study. But, ranking from least expensive to most is probably:

- Least expensive, Option 6
- Relatively inexpensive, Option 5 (using public meteorological data)
- Relatively inexpensive, Option 4
- Moderately expensive, Option 5 (setting up meteorological system at Hollister)
- Expensive, Option 2
- Most expensive, Option 1
- Most expensive, Option 3

We recommend that Option 6 be tried first. It is probably by far the least expensive option, has very high confidence level once "calibrated," and could well have a positive effect on community relations because FMC would show interest in noise control for site testing.

Finally, simply scheduling firing at times of day when communities tend to have minimal response to "impulse noise" from explosions can minimize complaints. Ref. 7 is an excellent summary of this aspect of noise abatement.

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